# BE PROJECT PROPOSAL

**ON**

# Design and Analysis of the Drive Train of an All-Terrain Vehicle


**Submitted by**

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## 1. Introduction

(Theme, Rational and Significance of Study)

Our project focuses on the study, design, analysis and manufacturing of the power transmission system of the BAJA all-terrain vehicle in association with team *Redshift Racing.* The project encompasses the study of the previous gearbox designs of the team, the Continuously Variable Transmission System (CVT), and the development of a new design for a better performance of the vehicle.

We focus on the optimization of the current design in terms of the cost of manufacture and the overall weight of the system, along with the improvement in the performance characteristics like acceleration, manoeuvrability and speed. We design the components on CATIA software while carrying out structural analysis on ANSYS software. The project involves the design of the entire two stage reduction gearbox, study of the performance characteristics of the CVT and its suitable modification with rigorous testing, design and manufacture of the rear-axle, and stability and mounting considerations of the entire system in particular.

The system we design has applications in other fields like agriculture, snow-mobiles, and ATV sports. CVT systems are an emerging trend in today's automobile industry. Due to its low cost, adaptability and compact assembly, CVT systems are suitable for applications in tractors and other agricultural equipment. The system we design implementing the CVT with low cost components such as the Briggs and Stratton Engine and gearbox considering mass production, is suited for these applications. Since it eliminates the use of a clutch and the need to switch gears, we believe it will revolutionize the industry in terms of such application in the near future.

## 2. <u>Proposed Research Work</u>

(Research Aims, Objectives Scope and Limitations)

Our current research work has three main subdivisions:

- Design and analysis of components including the gears, rear axle, housing, etc.
- Study of performance characteristics of the CVT and parameters that determine them. Study of CVT tuning and implementation.
- Study of Vibrational analysis of an engine. Experimental analysis of the current engine and suitable damping and mounting of the engine.

For the reduction gearbox, the following research work has being undertaken:

- Gear design and material selection. Gear manufacturing processes, their reliability, cost optimization. Hardening processes.
- Housing design. Materials properties required for sand casting. Design considerations for sand casting. Determination of tolerances for bearing seats, shaft designs. CNC machining for critical sections.
- Bearing and oil seals selection.
- System layout considerations for proper serviceability.
- FEA method for structural analysis.

For CVT systems:

- Understanding the working of the CVT systems. Forces and basic physics of the working.
- Study and determination of working parameters such as engagement RPM, shift RPM, etc.
- Components determining parameters for design such as properties of springs, torsional springs, flyweight design and manufacture, ramp angles for shift, etc
- Modification of existing system through reverse engineering for suitable performance.

Engine Mounting:

- Study of Vibrational analysis and vibration damping.
- Experimentation for vibration characteristics of the engine.
- Selection of suitable damping supports for reduction in transmitted vibrations.
- Nodal Analysis using ANSYS.

According to our market research, the proposed aim of the project can be achieved satisfactorily. Following are some limitations for the scope of the project:

- Pressure Die casting process is very costly for single product manufacture. Therefore, housing of the prototype will be manufactured using simple sand casting.
- Accurate vibrational analysis and exact material specifications need acute measurement and resources. The project will therefore look towards optimization with available resources.

## 3. Literature Review

- Clutch tuning handbook:

The CVT system consists of three components. The driver pulley, the driven pulley and the driving belt. The driven clutch consists of two stamped steel sheaves. One is a fixed sheave while the other is a movable one, with a pressure spring pushed against it. A centrifugal mechanism and along with the pressure springs controls the movement of the sheaves which varies the velocity ratio of the drivetrain.
Engagement speed: The engagement speed of the CVT is determined by the driver pressure spring and the flyweights.
Shift speed: The shift speed is the speed of the engine where the velocity ratio shifts from the lower ratio to the higher ratio. It is determined by the driver settings and the torsion spring and ramp angles on the driven.
The CVT should be tuned such that the engine runs in the power peak range under its entire range of operation. This can be achieved by varying the parameters like the spring constant, spring pretension, torsional stiffness of the spring, flyweight masses and ramp angle.

The following table illustrates the effect of tuning any clutch component on the performance of the system.

| TUNING OBJECTIVE | PRIMARY CLUTCH | | SECONDARY CLUTCH | |
|---|---|---|---|---|
| | PRESSURE SPRING | FLYWEIGHT | TORSION SPRING | HELIX CAM |
| Increase Shift Speed | Same Rate<br>Higher Engagement Load<br>Higher Full Shift Load | Lighter Flyweights | Same Rate<br>More Pretension | Less Cam Angle |
| Decrease Shift Speed | Same Rate<br>Less Engagement Load<br>Less Full Shift Load | Heavier Flyweights | Same Rate<br>Less Pretension | Larger Cam Angle |
| More RPM on Top End | More Rate<br>Same Engagement Load | Less Aggressive Curvature | More Rate<br>Same Pretension | Less Angle at End of Shift |
| Less RPM on Top End | Less Rate<br>Same Engagement Load | More Aggressive Curvature | Less Rate<br>Same Pretension | More Angle at End of Shift |
| More Aggressive Acceleration Less RPM at Beginning of Shift | More Rate<br>Less Engagement Load<br>Same Full Shift Load | More Aggressive Curvature | More Rate<br>Less Pretension | More Angle at Start of Shift |
| Less Aggressive Acceleration. More RPM at Beginning of Shift | Less Rate<br>More Engagement Load<br>Same Full Shift Load. | Less Aggressive Curvature<br>Grind Flat and Extend it Into Shift Curve | Same Rate<br>Higher Pretension | Less Angle at Start of Shift |
| Increase Engagement Speed | Less Rate, Add Shim<br>More Engagement Load<br>Same Full Shift Load | Grind Flat or Notch | No Change | No Change |

- Gearbox design:

For a reduction ratio of above 4, a multiple stage compound gear train is recommended. A two stage drive train is suited for the reduction ratio of about 14, with about 3.7 reduction ratio at each stage. Helical gears perform well in high speed operations where smooth transmission and low noise is essential. Helical gears are therefore suited for vehicle gear box systems. Full depth involute system is the most commonly used system for the gear profile suited for high speed transmissions.

Optimum number of teeth are selected on the basis of minimum weight and elimination of interference phenomenon. Modules are selected on the basis of bending strength and the wear strength of the tooth profiles. Lewis equation is adopted for the calculation of the bending and wear strengths of the gears. Uniform teeth profile, load application on a single tooth at a time, neglecting the radial and compressive forces, are some of the assumptions made during the calculations. To account for the neglected factors, a suitable factor of safety of 2.5 is selected for the selection of the modules.

Shaft design is based on the torsional equations. Length of shaft is determined considering limited elastic deformation during operation. Keys are designed considering shear and crushing failure. Standard sizes are adopted to approximate dimensions to the nearest values.

Bearings are selected based on the load ratings provided in the SKF bearing catalogue. Selection of bearings is based on the factors like axial loads, radial loads, average speed of operation and life of the bearing. Tapered roller bearings are suited in operations where a slight axial offset or angle, and where axial force is considerable. Tapered roller bearings also aid the ease of assembly of components. They are therefore suited in applications where there may be a slight error in manufacture of housings, and where frequent assembly and disassembly is required. Hence, they are selected over the other types of bearings available.

The housing design must be able to accommodate all the gear and shaft components within a compact space avoiding interference at the same time. Its design should also be such that assembly requires minimum time and is easy. It constitutes space for the gears, and seats for the bearings. The casing should sustain forces like weight of the gears, radial and axial reactions of the bearings, and any outside impact to protect the components from damage. The housing should also prevent leakage of lubricating oil. Housing design is based on basic principles of Machine Design and accepted theories of failure in tensile, bending and shear modes. Limited elastic deformation is also considered while design. Owing to the complex nature of the design, selection of one factor of safety for all design features is redundant. The design is thus first made based on judgement, analysed on a computational analysis software and then suitable changes are made towards optimality.

- Material Selection:

Materials are selected based on their properties, availability, cost and suitability for the required application. Some examples of properties considered for material selection are yield strength, ultimate tensile strength, hardness, ability for heat treatment, machinability, allowable working temperature.

The materials for gears are selected on the basis of tensile strength, compressive strength and suitability for surface hardening. Mild steel of grade EN24-EN36 are suitable for these applications.

The housing, which is to be manufactured by casting process demands a material which has high flow ability, rigidity, less porosity after casting, high tensile and compressive strength, good corrosion resistance. Low weight is also a dominant factor in the design of the housing. The LM series of aluminium is suited for sand casting. It is also light in weight. Considering optimization of cost, LM6 grade aluminium is used for casting.

- Analysis:

FEA is a numerical method, traditionally a branch of solid mechanics which is used to solve multiphysics problems. The ANSYS program is a powerful, multi-purpose analysis tool that can be used in a wide variety of engineering disciplines. It is an approximate method to solve engineering problems. Stress analysis for trusses, beams, and other simple structures are carried out based on dramatic simplification and idealization: mass concentrated at the centre of gravity, beam simplified as a line segment (same cross-section). Design is based on the calculation results of the idealized structure & a large safety factor (1.5-3) given by experience.

We need

- To understand the physical behaviours of a complex object (strength, heat transfer capability, fluid flow, etc.)
- To predict the performance and behaviour of the design.
- To calculate the safety margin.
- To identify the weakness of the design accurately.
- To identify the optimal design with confidence

Main steps in a typical ANSYS analysis:

- Model generation/importing model from a modelling software
- Simplifications, idealizations.
- Define materials/material properties.
- Generate finite element model (mesh).
- Specify boundary conditions.
- Obtain the solution.
- Review results:
- Plot/list results.
- Check for validity.

Model generation, defining material properties, element type and meshing is done in the Pre-processor. Application of loads and the solution is performed in the Solution Processor. Finally, the results are viewed in the General Postprocessor

<u>ANSYS Pre-processor</u>

Model generation is conducted in this processor, which involves material definition, creation of a solid model, and, finally, meshing. Important tasks within this processor are:

• Specify element type.
• Define real constants (if required by the element type).
• Define material properties,
• Create the model geometry.
• Generate the mesh.

<u>ANSYS Solution Processor</u>

This processor is used for obtaining the solution for the finite element model that is generated within the Pre-processor, Important tasks within this processor are:

• Define analysis type and analysis options,
• Specify boundary conditions.
• Obtain solution.

<u>ANSYS General Postprocessor</u>

In this processor, the results at a specific time (if the analysis type is transient) over the entire or a portion of the model are reviewed. This includes the plotting of contours, vector displays, deformed shapes, and listings of the results in tabular format for stresses deformations factor of safety. From the results obtained the design is optimize.

## 4. Methodology

- Study of the current design. Analysis of its drawbacks and plus points.
- Plotting of the necessary improvements/changes.
- Market research for materials, manufacturing processes, cost requirements.
- Finalising the project plan and cost estimation.
- Theoretical calculations and CAD.
- Analysis of component designs, finalising of designs.
- Manufacturing processes, purchase of supplemental parts.
- Assembly of the components.
- Testing of the assembly.
- Experimentation and measurement of performance parameters.
- CVT tuning.
- Engine vibration analysis.

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